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Design And Performance Evaluation of a Novel Double Cyclone

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1. Introduction

Cyclones are one of the most widely used industrial dust collectors. They are very rugged in design, reliable in performance and economy in maintenance. However, there are several problems concerning the separation of particles from the air in conventional cyclones. First, the collection efficiency of fine particles is not high enough when conventional flow cyclone is operated at ordinary flowrates. The general cut size of this kind of cyclone is about 5㎛. Second, cyclones generally do not provide sharp particle-size separation between the collected and uncollected particles.

In this study, a new cyclone design is introduced in an attempt to increase the particle collection efficiency and to overcome the limitations of existing cyclone types. In the new design (patents applied for), an additional cylinder wall was introduced into the cyclone body which separates the total inner space into two annular sections. One is between the cyclone wall and the cylinder wall and the other is between the cylinder wall and a removable exit tube which faces down instead of facing up in a regular cyclone design (Figure 1). Due to the design, entrained air was forced to flow one more vortex inside the cyclone body and particles can be collected both on the cyclone wall and on the cylinder wall by strong centrifugal force. Deposited particles descend to the lower part of the device and may be wasted by removing the exit tube. This device looks like two cyclones combined co-axially together and was named Double Cyclone. The primary objective of the present study is to introduce the new design and to compare the performance of the double cyclone with a conventional cyclone. Since the centrifugal force plays a very important role in cyclone performance and since one more vortex is introduced in the double cyclone, the collection efficiency of the double cyclone is expected to be higher than that of the conventional cyclone.

2. Experiment Method

Evaluation of air sampling device is not an easy undertaking, and in most cases, the utility of new instruments is assessed by comparative tests with widely used and well-characterized standard samplers. Thus, this study has as its focus the performance evaluation of the double cyclone by comparing the particle collection efficiency of double cyclone with that of a conventional cyclone, namely a high efficiency Stairmand cyclone. The experimental setup has been described in detail in a previous publication (Zhu and Lee, 1999).The system was consisted of an aerosol generator, a test cyclone and an aerosol detector. Monodisperse polystyrene latex (PSL) particles were employed for all experiments.

3. Results and Discussion

To compare the performance of the double cyclone and the conventional cyclone, Figure 2 shows the particle collection efficiency versus particle diameter for both cyclones at 10 L/min and 40 L/min. It is seen in the Figure 2, at a fixed flowrate, the "S" shape curve of the double cyclone is always to the left of that of the conventional cyclone indicating a higher collection efficiency or a lower 50% cut size (d_{50}). Most recently, many researchers found that d_{50} was not the best indicator for evaluating cyclone performance. They found that a smaller cyclone tends to have a higher collection efficiency than a bigger cyclone with identical dimensional design ratio. To compare cyclones with different dimension values, d_{50}/Dc (where Dc is cyclone body diameter) may be a better choice (Moore and McFarland, 1995; Kenny and Gussman, 1997; Liden and Gudmundsson, 1997). In order to evaluate the performance of the double cyclone in a comprehensive way, several previous experiment results were added to Figure 3 which depicts the normalized cut size versus flowrates. It is seen that except for the lowest flowrate region (Kenny and Gussman, 1995) and the highest flowrate region (Zhu and Lee, 1999), the double cyclone always provides a smaller normalized cut size at a fixed flowrate than other conventional cyclones.

As mentioned before, cyclones generally have difficulties to provide a sharp particle-size separation between the collected and uncollected particles. In fact, the sampling effectiveness of a cyclone is characterized not only by the normalized cut size, but also by a slope (or geometric standard deviation) which is the square root of the ratio of the diameter of particles excluded by the inlet with an 84% efficiency (d_{84}) to the diameter removed with a 16% efficiency (d_{16}). The slopes of both the double cyclone and the test conventional cyclone at different flowrates were calculated and listed in Table 1. It is noted that the slope of the double cyclone is always smaller than that of the test conventional cyclone indicating a sharper particle-size separation characteristics. Thus, at a fixed flowrate, the double cyclone provides a smaller normalized cut size and a stiffer particle-size separation curve. Both contribute to a more efficiency cyclone design.

Another important issue in cyclone design is energy consuming which may be indirectly evaluated by examining the pressure drop across the cyclone. Since the pressure drop is basically a measure of the energy that a cyclone consumes and the normalized cut size characterizes the effectiveness of a cyclone design, it will be very informative to correlate these two factors and examine the inner relationship between them. To do this, Figure 4 was prepared depicting the logarithm of the total pressure drop versus the logarithm of the normalized cut size for both the double cyclone and conventional cyclones studied by previous researchers and in this study, where the data points for each cyclone correspond to the gas flowrates tested. A linear relationship is observed for most cyclone designs in Figure 4. In addition, the regression line for the double cyclone is located to the left of those for conventional cyclones which indicates a better cyclone design, in that the double cyclone allows lower pressure drop or consumes less energy at the same normalized cut size. Thus, it is concluded, the double cyclone is found a more efficient, and less costly, thereby, a superior design than conventional cyclones.

Table 1. Slopes of particle-size separation characteristic for the double cyclone and the test conventional cyclone at different flowrates.

Flowrate (L/min)	Double Cyclone	Conventional Cyclone
10	1.39	1.58
20	1.38	1.57
30	1.37	1.55
40	1.37	1.53

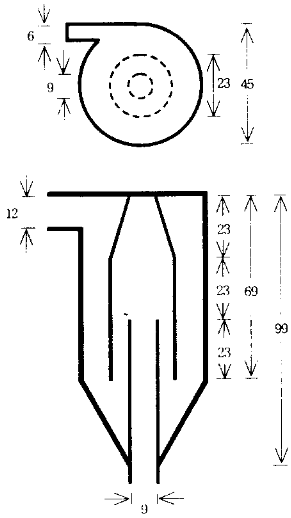

Figure 1. Schematic diagram of Double Cyclone(unit:㎜).

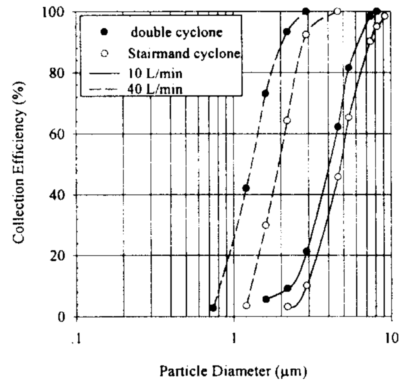

Figure 2. Particle collection efficiency of Double Cyclone and the test Stairmand cyclones at 10 L/min and 40 L/min.

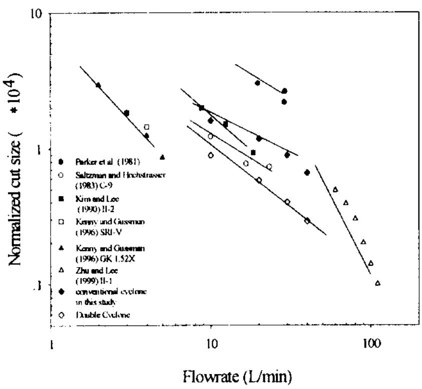

Figure 3. Flowrate versus normalized cut size for different cyclones.

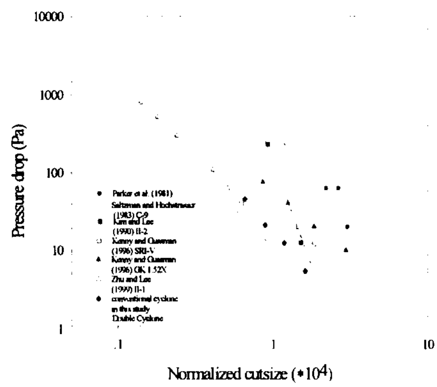

Figure 4. Pressure drop versus normalized cut size for the different cyclones.

REFERENCE

Griffiths, W.D. and Boysan, F. (1996) Computational fluid dynamics (CFD) and empirical modelling of the performance of a number of cyclone samplers. *J. Aerosol Sci.*, 27/2, 281-304.

Kenny, L. C. and Gussman, R. A. (1995) Characterization and modelling of a family of cyclone aerosol preseparators. *J. Aerosol Sci.* 26, S777-S778.

Liden, G. and Gudmundsson, A. (1997) Semi-empirical modelling to generalise the dependence of cyclone collection efficiency on operating conditions and cyclone design. *J. Aerosol Sci.* 28, 853-874.

Moore, M. E. and McFarland. A. R. (1995) Design methodology for multiple inlet cyclones. *Environ. Sci. Technol.* 30,271-276.

Zhu, Y. and Lee, K. W. (1999) Experimental study on small cyclones operating at high flowrates. Accepted for publication in *J. Aerosol Sci.*.